DRAFT

Export Operations Flexibility Analysis

CALFED Bay-Delta Program
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916-657-2666

December 23, 1999

Integrated Storage Investigation

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Section 1 - Introduction

The CALFED Bay-Delta Program is refining a Water Management Strategy to provide broad guidance for selecting and implementing water management tools over the implementation phase of the Program, in consideration of all Program objectives. To provide a basis for evaluating alternative water management strategies, CALFED is developing and implementing a Water Management Strategy Evaluation Framework (WMSEF). This framework is designed to support the decision-making process and help arrive at a broadly supportable Water Management Strategy. It focuses on: (1) establishing a comprehensive list of performance measures (or evaluation criteria) that can be used to compare the relative value of alternatives, and (2) encouraging a creative approach to the development of the successful alternative strategies.

An important aspect of any water management strategy is the flexibility it provides for dealing with multiple objectives during times of conflict. For example, how well does the strategy provide for meeting water supply reliability objectives while concurrently allowing for export curtailments during times most sensitive to fisheries? CALFED initiated this export operations flexibility analysis to provide insight into how new storage and conveyance facilities, demand reduction measures, and regulatory flexibility might contribute to improvement in system operational flexibility. Analytical concepts developed through this effort will be further explored under the WMSEF.

There are a variety of potential approaches to defining operational flexibility. For this evaluation, the ability to curtail water project exports from the Delta for a given number of days over any year is compared to water supply reliability provided under a variety of assumptions regarding level of demand, new facilities, and regulatory flexibility. Specifically, the incremental water supply benefits provided with various operating rules and/or new facilities were fully converted into reduced days of project exports.

1.1 Department of Water Resources Simulation Model

The analysis was performed using The Department of Water Resources (DWR) project operations model (DWRSIM). DWRSIM was used to analyze the potential effects of proposed new features, such as additional reservoir storage or Delta export conveyance, as well as changes to criteria controlling project operations. The model simulates CVP and SWP systems of reservoirs and conveyance facilities and calculates flows on a monthly time step using a historical 73-year hydrologic sequence (water years 1922-94). Historical runoff patterns have been normalized to 2020-level land use. The DWRSIM model incorporates the Metropolitan Water District of Southern California (MWD) Fish Trigger Methodology as an option in its Delta export restriction calculations.

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1.2 Information Sources

To define a process of applying Delta export capacity restrictions, a number of information sources were reviewed:

Historical Salvage Data. MWD compiled data representing the density of Steelhead, Delta Smelt, Salmon, Splittail, and Striped Bass at the CVP and SWP Banks Pumping Plant from 1979 through 1997.

Fish Trigger Methodology. MWD Fish Trigger Methodology based on eighteen years of historical salvage data. The methodology assumes thresholds for critical density levels of fish species salvage and/or critical rate of change in density levels of fish species salvage. Export pumping is curtailed when critical thresholds are reached. The methodology is a viable option for managing fish salvage at the Delta export pumping plants. This methodology has been used to support the Environmental Water Account (EWA)/Flexible Operations gaming exercises.

CalFed EWA/Flexible Operations Gaming Exercises. Exercises examined actions, tools and assets that may benefit Delta and upstream fisheries without harming CVP/SWP project benefits and reliability, based on simulated and historical data.

Historical CVP/SWP Operations Data. Historical CVP/SWP operations data, documenting fish salvage occurrences and related operations.

It is important to note that the analysis reflects simplifications of information presented in these sources. For example, the timing when a fish species appear at the Delta export pumps may vary over several months. Variation in timing can be dictated by hydrologic parameters or other factors. The utility of extending this analysis to consider fish timing variations is uncertain without knowledge of the factors that control the variation.

Section 2 – Export Flexibility Assumptions

2.1 Schedules of Delta Export Capacity Reduction

Schedules representing the range of Delta export capacity were developed to analyze operational flexibility benefits. Operational flexibility is measured by the number of days per year that export capacity was restricted. Delta export pumping capacity was limited during periods when Delta fisheries are potentially sensitive to Delta exports, according to an assumed capacity reduction schedule. The environmental benefits due to reduced salvage of various fish species at the Delta export pumps were not determined.

Table 1 presents the range of Delta export capacity reduction evaluated. Eighteen schedules were chosen to represent the range of Delta export capacity, from zero to 159 days of capacity restriction per year. Schedule 1 is the most aggressive schedule, restricting export capacity up to 159 days per year. Each schedule incrementally reduces the export capacity restrictions. Schedule 18 does not impose export capacity restrictions.

The Delta export pumping capacity schedule was interpreted according to the following rules:

1) Combined SWP and CVP Delta exports were restricted to a total of 2,250 cfs for the number of days specified by the schedule;
2) The restricted days were evenly distributed throughout each month according to the number of days specified by the schedule;
3) The SWP and CVP were assumed to operate around the restricted days, within each month; and
4) The SWP and CVP were allowed to operate around the restricted months, within each year.

Table 1: Number of Days Total Delta Export Pumping Capacity Reduced to 2250 CFS:

Schedule Number	Annual Total	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	159	0	0	16	16	16	16	24	31	24	16	0	0
2	151	0	0	8	16	16	16	24	31	24	16	0	0
3	143	0	0	8	16	8	16	24	31	24	16	0	0
4	135	0	0	8	16	8	16	24	31	24	8	0	0
5	127	0	0	8	8	8	16	24	31	24	8	0	0
6	111	0	0	8	8	0	16	24	31	24	0	0	0
7	103	0	0	8	8	0	8	24	31	24	0	0	0
8	87	0	0	0	8	0	8	24	31	16	0	0	0
9	80	0	0	0	8	0	8	24	24	16	0	0	0
10	72	0	0	0	8	0	8	16	24	16	0	0	0
11	56	0	0	0	0	0	8	16	24	8	0	0	0
12	48	0	0	0	0	0	0	16	24	8	0	0	0
13	40	0	0	0	0	0	0	8	24	8	0	0	0
14	32	0	0	0	0	0	0	8	24	0	0	0	0
15	24	0	0	0	0	0	0	8	16	0	0	0	0
16	16	0	0	0	0	0	0	8	8	0	0	0	0
17	8	0	0	0	0	0	0	0	8	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0

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2.2 Schedules of Allowable Delta Export/Inflow Ratio Relaxation

Relaxation of allowable Delta export/inflow ratios during peak summer and fall SWP/CVP delivery months was developed to analyze operational flexibility benefits. The export operations flexibility analysis examined benefits from relaxation of allowable Delta export/inflow ratios during peak summer and fall SWP/CVP delivery months. Operational flexibility analysis included consideration of forecast delivery shortages due to relaxation of allowable Delta export/inflow ratio to see if such relaxation could be used to overcome operations shortages, or if additional operational flexibility could be applied with the aid of the relaxation. Pumping capacity reductions were imposed from December through July, when environmental concerns are apparent.

Schedule 1 was developed for evaluating allowable Delta export/inflow ratio relaxation in the peak delivery months, with a 75% allowable ratio in August and September. The allowable ratio for these two months under the 1995 State Water Resources Control Board Water Quality Control Plan is 65%. Relaxation of the allowable Delta export/inflow ratio during the peak summer months could be utilized to make up for SWP/CVP export reductions during the previous spring, since additional exports under the relaxation are likely to be used for either immediate or near-term delivery. Schedule 2 includes a 75% allowable ratio in October and November, in addition to the Schedule 1 Delta export/inflow ratio relaxation. The Delta export/inflow ratio did not exceed 75%. Figure 1 depicts the schedules of allowable Delta export/inflow ratio relaxation.

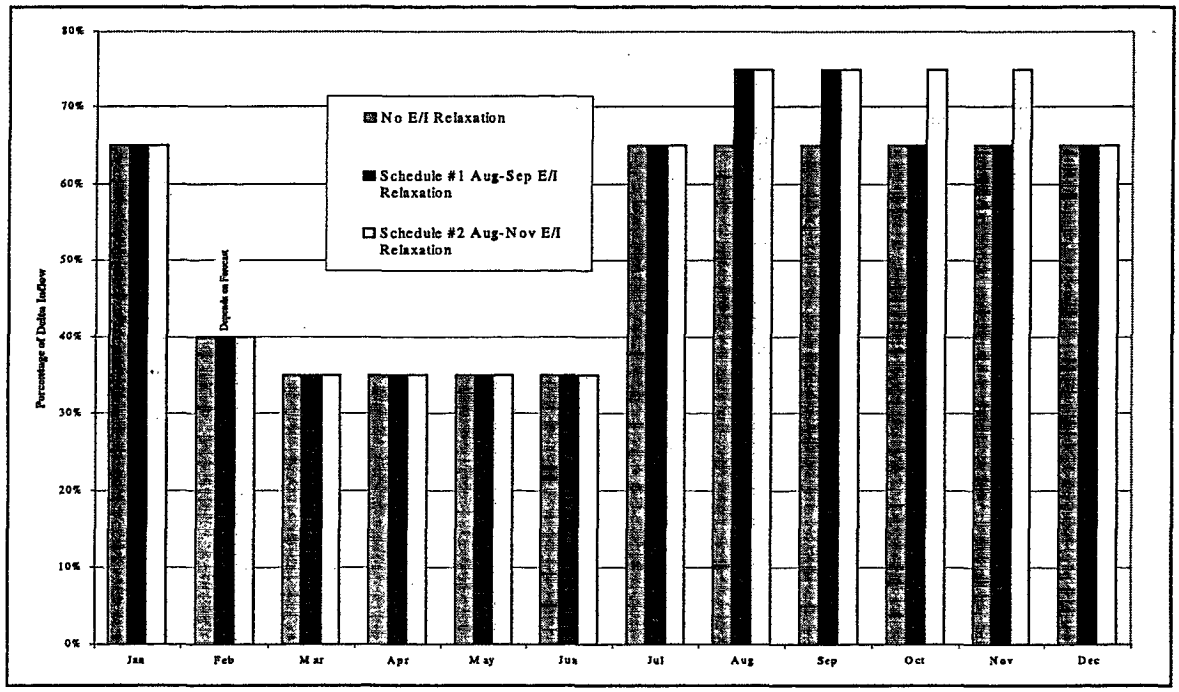

Figure #1: Schedules of Allowable Delta Export/Delta Inflow Ratio Relaxation.

Section 3 – System Operations Analysis

The analysis considered two bookend sets of water management assumptions (Criterion A and B) that describe a wide range of potential future demands for Bay-Delta water supply and requirements for environmental protection. These criterion are described in the CALFED Bay-Delta Program Draft Programmatic EIS/EIR, June 1999. Water management criteria A assumes higher environmental restrictions and lower CVP/SWP project demands. Water management criteria B assumes lower environmental restrictions and higher CVP/SWP project demands.

The analysis focused on four levels of Delta storage and conveyance facility configurations for each water management criteria.

1) No additional facilities (No Action).
2) Increased Delta export conveyance capacity configuration, including SDI and JPOD modifications.
3) Increased north-of-Delta surface storage (NDSS) configuration, including modifications for additional storage north of the Delta, in addition to SDI and JPOD.
4) Increased full storage capacity configuration, including 4.5 MAF additional storage facilities north and south of the Delta, in addition to SDI and JPOD.

The first step in the analysis was to apply the eighteen Delta export capacity reduction schedules to determine the relationship between the average number of days pumping capacity was reduced to 2,500cfs and total exports. Figure 2 depicts graphical representation of the correlation between exports and the number of days pumping capacity is restricted, the results of schedule 1 through 18 are indicated by markers.

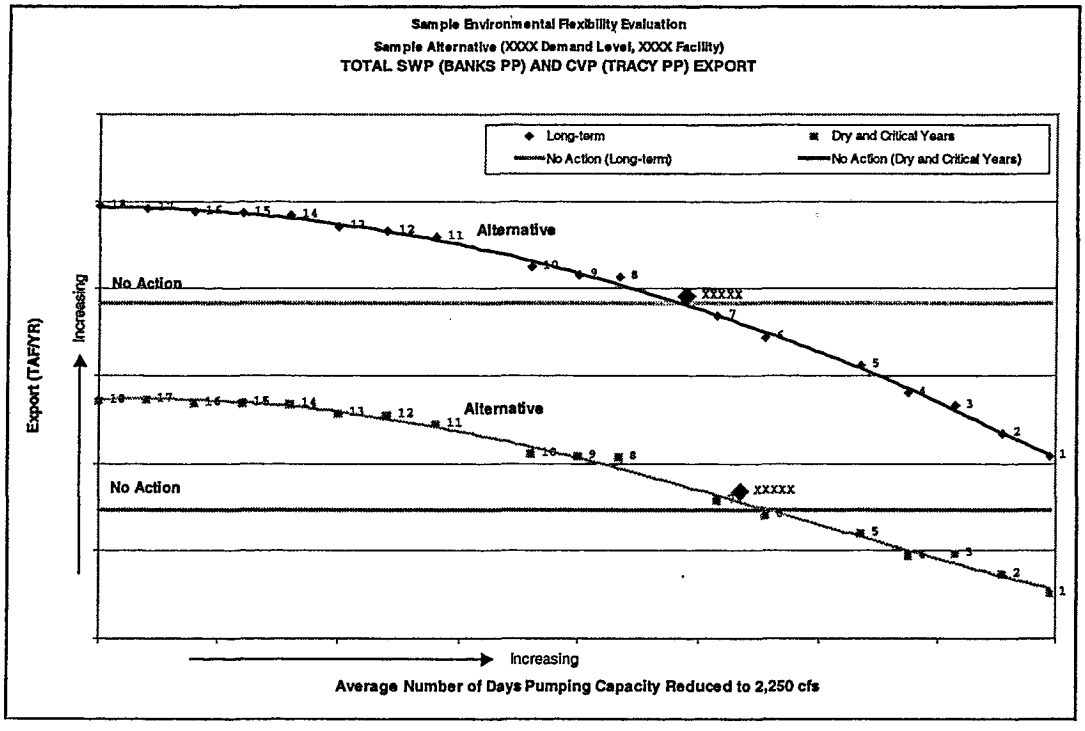

Figure 2: Sample Evaluation of relationship between Delta export and number of days pumping capacity reduced, with selection of the maximum Export Operations Flexibility.

Based on these results a trend-line has been plotted for long term years (all years) and Dry and Critical years (classification based on 1995 WQCP 40-30-30 year type index). In addition, the No Action average annual Delta export values for all years and for Critical and Dry years have been plotted. Results were graphed for each Delta conveyance/storage facility and given water management criteria combination.

3.1 Replacement of Water Management Criteria A Delta Restrictions

The additional Delta operational restrictions included under water management criteria A were replaced with an equivalent Delta export capacity reduction schedule. The criteria replaced restrictions in Delta flows that indirectly restricted Delta exports. By replacing the water management criteria A Delta restrictions, the No Action simulation operations flexibility was measured and made comparable to the maximum extent operations flexibility assessed in all other water management criteria A simulations. The newly redefined Delta restrictions were incorporated into all water management criteria A simulations (for this analysis only).

The Delta restrictions incorporated into the original water management criteria A include:

1) Reduction in exports to 1,100 cfs for 10 days in February if the January SJR flow at Vernalis is greater than the upper 25th percentile (approximately 4,150 cfs)
2) In February and March a minimum Qwest of 1,000 cfs is maintained if the January 8 River runoff is < 1.0 MAF. If the January 8 River runoff is > 1.0 MAF, a minimum Qwest of 0 cfs is maintained.
3) A minimum Qwest of 0 cfs is maintained in December and January if the Nov. 4 - River runoff is > 1.1 MAF. Additionally, if the Dec. 4 River runoff is between 0.75 and 1.3 MAF, a minimum Qwest of 0 cfs is maintained in January.
4) A minimum Qwest of 1,000 cfs is maintained from April through June.
5) VAMP exports criteria is extended to 61 days in April and May.

Item 1 and 5 are direct restrictions on Delta exports. It is important to note that under the 1995 WQCP, the Delta Cross Channel Gate is closed for 45 days during November through January, and is always closed during February through May 20. Additionally, the Delta Cross Channel Gate is assumed closed during October through January, due to CVPIA b(2) Delta Actions. Items 2, 3 and 4 become indirect restrictions on Delta exports, because there is no allowable conveyance of Sacramento River flows to the Delta export pumps.

These restrictions were removed from the No Action simulation under water management criteria A. Then a year type-varied Delta export capacity reduction schedule was applied that nearly restricted the Delta exports of the revised simulation to an equivalent level as the original No Action simulation. The procedure used was very similar to that documented in section: Determination of Relationships between Delta exports and number of days pumping capacity was reduced. The operations flexibility applied to match the original No Action was then used to replace the Delta restrictions in all simulations with water management criteria A. The operations flexibility applied was presented as the water management criteria A No Action result in Table 2 and Figure 3.

3.2 Results

Graphs for the eighteen Delta export capacity reduction schedules are presented in the Appendix. The resulting graphs depict the operational flexibility gained and water supply benefit foregone due to application of operational flexibility for environmental benefit. The results show that as the number of days pumping capacity reductions increase, the Delta export value decreases. As the number of days pumping capacity reduced continues to increase the Delta export value decreases with a steeper slope. This occurs because as the number of days of restriction increased there are fewer unrestricted days remaining for project re-operation to avoid reduction in Delta exports. It should also be noted that the slope of Delta export decrease appears to stay constant when no re-operation of Delta exports is being accomplished by the CVP and SWP projects (the amount of Delta export lost equals the capacity reduction for the duration of a day). In the case of these alternatives, typically: 25 TAF/Day = [[10,300 CFS + 4,600 CFS – 2,250 CFS] * 1.9835 AF/Day-CFS] / [1000 AF/TAF]).

3.3 Selection of Maximum Export Operational Flexibility Schedule

The Delta export capacity reduction schedule closest to the point where the alternative trend-line crosses the Delta export level of the No Action simulation was selected as the maximum extent of export operational flexibility (refer to Figure 2). The maximum export operational flexibility is the schedule's total annual number of days export capacity was reduced for the schedule selected. It should be noted that the long-term trend-line does not cross the No Action Delta export level at the same number of days as the Dry and Critical years trend-line. For this reason, the Delta export capacity reduction schedule selected in each year must vary on a year type basis. The 1995 WQCP 40-30-30 year type index was used for this purpose. Table 2 identifies the maximum export operational flexibility schedule, varied by year type, and the number of days export capacity was reduced under the schedule.

Table 2: Maximum Extent Export Operations Flexibility:

	Year Type-Varied Schedule Designator (Marker Label)	Critical	Dry	Below Normal	Above Normal	Wet
		(Schedule/Days)				
Water Management Criteria A						
"No Action"	55909	5/127	5/127	9/80	12/48	9/80
SDI+JPOD	55872	5/127	5/127	8/87	7/103	2/151
SDI+JPOD+NDSS	12642	1/159	2/151	6/111	4/135	2/151
SDI+JPOD+FULL	12431	1/159	2/151	4/135	3/143	1/159
Water Management Criteria B						
"No Action"	n/a	n/a	n/a	n/a	n/a	n/a
SDI+JPOD	00098	12/48	12/48	12/48	9/80	8/87
SDI+JPOD+NDSS	39987	3/143	9/80	9/80	8/87	7/103
SDI+JPOD+FULL	38976	3/143	8/87	9/80	7/103	6/111

The appendix to this document presents graphics for each alternative considered. In determining the maximum export operational flexibility schedules, only Schedule 1 through 9 and Schedule 12 were used. Schedule 12 is designated with a "0" in marker labels and legends. The designator is the single digit Delta export capacity reduction schedule used in each year type from Critical through to Wet. Figure 3 and 4 present the tabulated results.

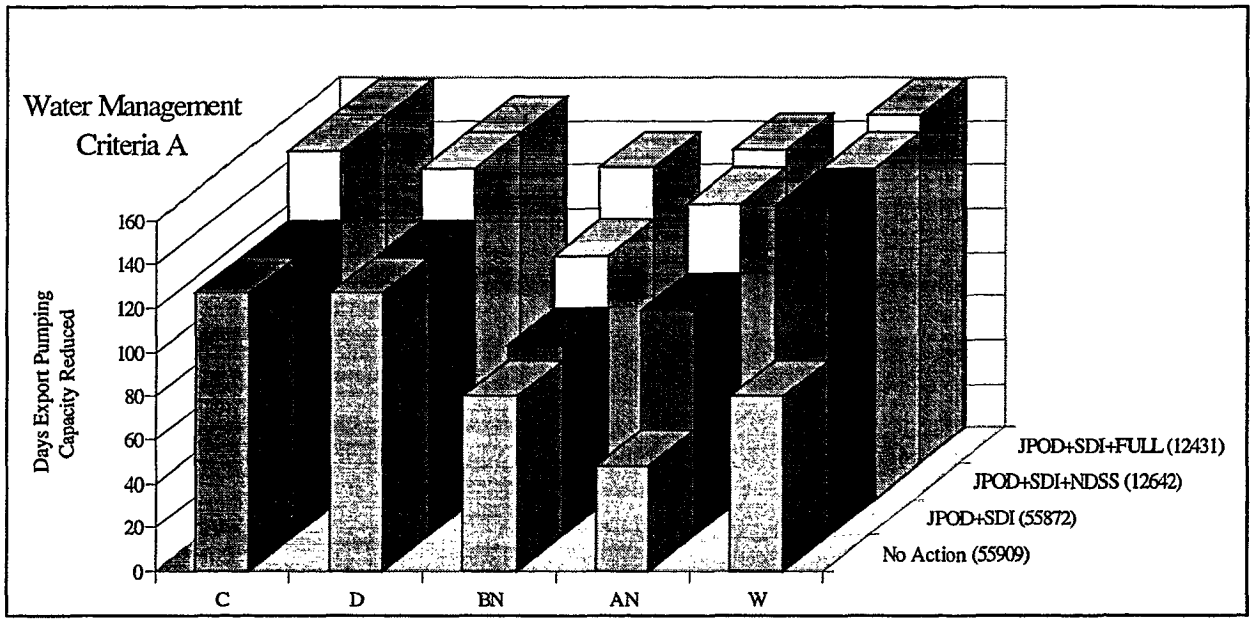

Figure #3: Maximum Extent Export Operations Flexibility of Alternatives - Water Management Criteria A

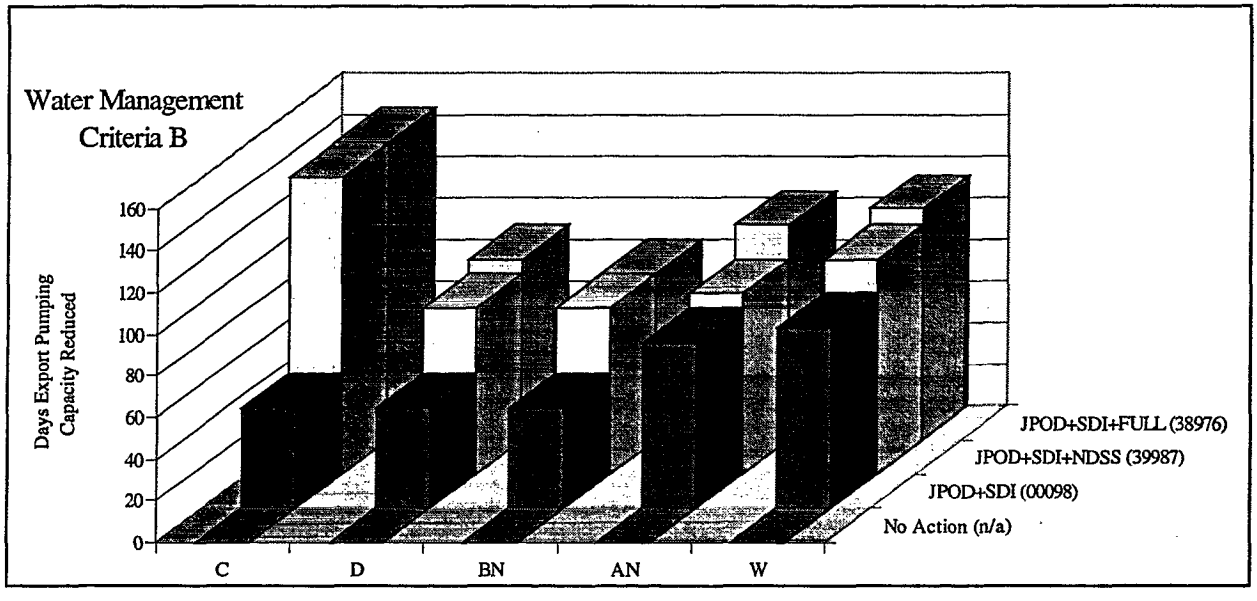

Figure #4: Maximum Extent Export Operations Flexibility of Alternatives - Water Management Criteria B

As shown in Figure 3 (Alternative A) and 4 (Alternative B), increases in export operational flexibility results in diminishing Delta exports. Increased operational flexibility can provide increase environmental benefits, whereas reduction in the use of export operational flexibility results in water supply that can be used for other benefits. Table 3 depicts the maximum export operational flexibility with a comparative result in number of days Delta export capacity reduced, and with a comparative result in Delta export forgone by application of the alternative benefits to export operational flexibility.

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Table #3: Comparison of Maximum Extent of Export Operations Flexibility:

	Dry and Critical Years	All Years
	Average annual Delta export foregone (TAF) / Average annual additional days of export capacity reduction	
Water Management Criteria A		
SDI+JPOD	-37 / 0	62 / 29
SDI+JPOD+NDSS	216 / 27	246 / 49
SDI+JPOD+FULL	201 / 27	535 / 57
Water Management Criteria B		
SDI+JPOD	0 / 48 (0*)	174 / 64 (16*)
SDI+JPOD+NDSS	517** / 107 (59*)	630** / 98 (50*)
SDI+JPOD+FULL	506** / 111 (63*)	763** / 104 (56*)

* These values in () are 48 days less – if schedule 12 is assumed to be included in the No Action for Alternative B
** These values are from simulations that had forecast delivery shortages, the DWRSIM model substantially failed to meet delivery allocations for various reasons (see section on adjustment for forecast delivery shortages).

3.4 Evaluation of Allowable Delta Export/Inflow Ratio Relaxation

The last step in the evaluation was to assess the effect of relaxation of the allowable Delta export/inflow ratio on export operations flexibility results. Two options for Delta export/inflow ratio relaxation were considered.

The first option considered relaxation of the Delta export/inflow ratio during the peak delivery months of August and September. The second option considered further Delta export/inflow ratio relaxation during the fall months, October and November. Figure 5 shows an example of the effect of Delta export/inflow relaxation.

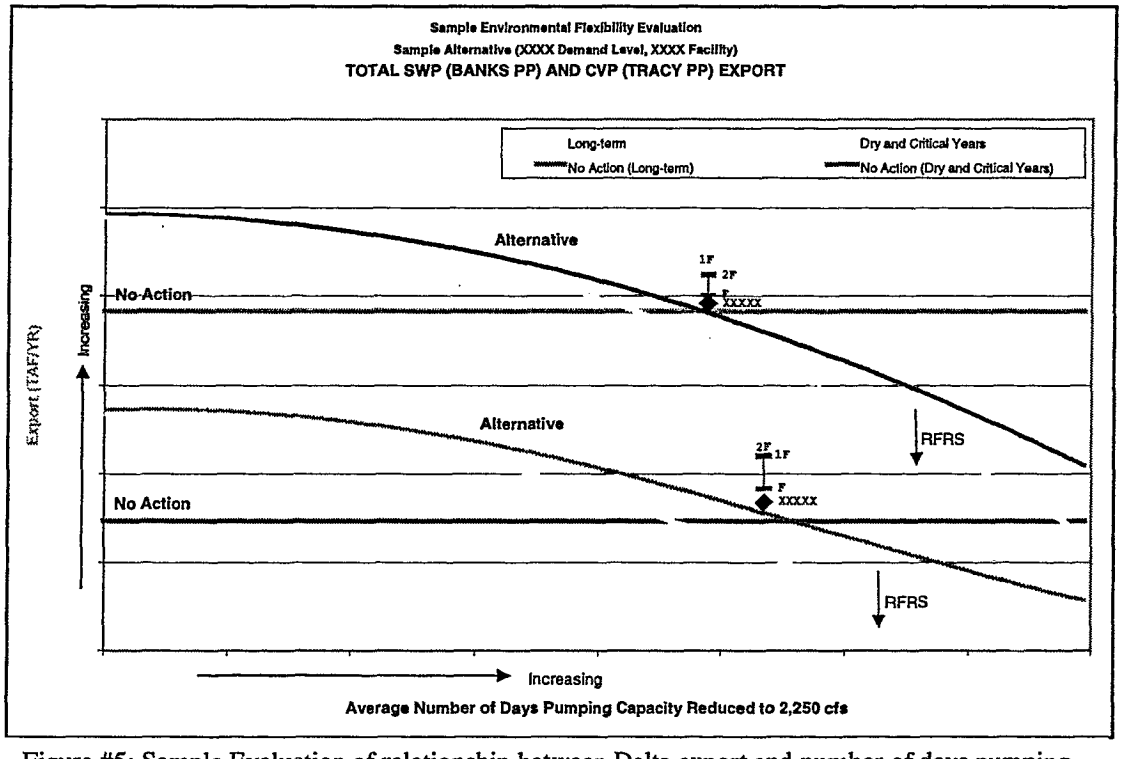

Figure #5: Sample Evaluation of relationship between Delta export and number of days pumping capacity reduced, showing relationship adjusted for forecast delivery shortages.

In Figure 5, label "1F" compared to label "F" represents the change in Delta export due to the relaxation of the ratio in August and September, and label "2F" compared to label "1F" represents the change in Delta export due to the relaxation of the ratio in October and November. The appendix to this document presents graphics for each alternative considered.

Table 4 represents the comparative change in Delta exports due to the August and September relaxation of the Delta export/ inflow ratio. Table 5 represents the comparative change in Delta exports due to the October and November ratio relaxation, in addition to the August and September ratio relaxation above.

Table 4: Average Annual Delta Export Change (TAF) from Delta Export/Delta Inflow Relaxation Schedule 1:

	Dry and Critical Years	All Years
Water Management Criteria A		
SDI+JPOD	-117	-44
SDI+JPOD+NDSS	76	39
SDI+JPOD+FULL	62	68
Water Management Criteria B		
SDI+JPOD	-109	-59
SDI+JPOD+NDSS	181	119
SDI+JPOD+FULL	179	147

Table 5: Further Average Annual Delta Export Change from Delta Export/Delta Inflow Relaxation Schedule 2 Compared to Schedule 1:

	Dry and Critical Years	All Years
Water Management Criteria A		
SDI+JPOD	-31	-55
SDI+JPOD+NDSS	-46	-53
SDI+JPOD+FULL	-10	-29
Water Management Criteria B		
SDI+JPOD	-67	-73
SDI+JPOD+NDSS	7	-10
SDI+JPOD+FULL	16	-18

Under Delta export/inflow relaxation Schedule 1, the ratio relaxation in August and September was only beneficial under alternatives that included additional storage facilities. The additional ratio relaxation in October and November (referring to Schedule 1 and 2), was beneficial only in Dry and Critical years under water management criteria B, alternatives that included additional storage facilities. This additional benefit is minor and of comparable magnitude of DWRSIM model resolution.

The increase in Delta exports brought about by the relaxation of the Delta export/Delta inflow in August and September (Schedule 1), occur concurrently with the occurrence of forecast delivery shortages. Detailed graphics in the appendix support this conclusion.

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Section 3.5 Special Study: Export Operations Flexibility Sensitivity to Demand Increase

Water Management Criteria A and B CVP/SWP project demands south-of-Delta vary by up to 900 TAF/YR, due to demand increases lead to increases in Delta exports. An average increase in Delta exports may not occur if additional export capacity restrictions occur coincidental to increased demands. In such a case the increase in demands would be met without difficulty. In other years, even though demand has increased, the amount of unmet demand has increased, perhaps leading to a reduced allocation overall.

A special study was performed to evaluate the sensitivity of the analysis results with regard to demand increases. A 2020 level demand study under water management criteria B was compared to a 1995 level demand study under water management criteria B. The application of operational flexibility schedules was made to the 2020 level demand study in the same way as the previously described evaluation of the maximum operational flexibility.

Due to increases in CVP/SWP demands, an increase in export restrictions during Above Normal and Below Normal year types was needed to offset the resulting increase in Delta exports that would otherwise occur. The increase in export restrictions amounted to approximately 20 days of additional reduction of pumping capacity to 2,250 CFS.

Section 4 – Modeling Considerations

4.1 Adjustment for Shortages in Forecast Deliveries

The DWRSIM model uses a specialized forecast based Delivery Logic to determine the allocation of deliveries to CVP and SWP south-of-Delta contractors. Delivery Logic is does not consider potential Delta export capacity constraints.

The Delivery Logic is uncertain in two ways: (1) if supply allocation is too large water supply may be depleted rapidly, resulting in insufficient supplies during critical drought periods; and (2) if supply allocation is too small water supply may be lost through increased uncontrolled spills and surpluses. This inability to accomplish allocated deliveries is denoted in this document as forecast delivery shortages. To achieve an optimal balance in operations, the model user must provide Delivery Logic operations rules that balance both risks and achieve SWP/CVP operational objectives. Delivery Logic operation rules are modified to minimize large allocations and Delta export capacity restrictions, because if the south-of-Delta storage reserve is depleted too rapidly deliveries during peak periods (July through September) will not be met.

Forecast delivery shortages affecting the results of Table 3 were footnoted. Due to these substantial forecast delivery shortages, the analysis results are questionable for two alternatives: (1) SDI+JPOD+NDSS; and (2) SDI+JPOD+FULL. These shortages can be reduced by adjust the Delivery Logic operations rules to fully consider conveyance restriction. The process would require adjusting the Delivery Logic operations rules to consider conveyance restriction repeating the entire process, a long laborious process. Therefore, the adjustment was completed through adjustment annual Delta export results. Average annual Delta export results were adjusted by subtracting 25% of the average annual operation shortage (the amount by which the projects failed to meet each year's delivery allocation).

Twenty five percent of the average annual operations was selected based upon experience and verified to ensure that the fraction selected was appropriate. The verification analysis consisted of reiterating a sample simulation (one with substantial operations shortages). Operation rules of each iteration were modified to reduce the frequency and magnitude of forecast delivery shortages. Average annual Delta exports, average forecast delivery shortages, and the adjusted average annual Delta exports were traced. As shortages were reduced, Delta exports declined and became more closely comparable to the adjusted Delta export result. After a few iterations, even though operations rule adjustments were still warranted (forecast delivery shortages still existed), the difference between successive adjusted Delta export results became inconsequential. It was determined at this point, that the selection of the fraction of 25% was sufficient for use in the analysis.

With the selection of the adjustment fraction of 25%, all the simulation results used to develop the relationships between Delta export and number of days pumping capacity reduced were adjusted to take operations shortages into account. The sample evaluation is presented in Figure 5, to illustrate the adjustment. The graphic uses a label, "RFRS", to denote the adjusted relationships. (The "RFRS" label refers the direction the "Delta export" – "Number of days pumping capacity reduced" relationship is moved by re-operation of the simulation for reduction

of forecast delivery shortages). The appendix to this document presents graphics for each alternative considered.

Based upon the adjusted relationship between Delta export and number of days pumping capacity reduced, when substantial forecast delivery shortages occur in the simulation the initial results reported in Table 3 show optimistic operational flexibility.

Section 4.2 Use of South-of-Delta Rule Curve

Completion of analysis of Delta export/inflow ratio relaxation schedules required modifications to the South of Delta Rule Curve, an operations rule in DWRSIM. This operations rule is a device to balance stored water between the south-of-Delta storage and upstream north-of-Delta storage facilities. South-of-Delta stored water has already been conveyed through the delta and secured, however, south-of-Delta storage facilities are the only locations where exported Delta surpluses may be stored. As indicated in the discussion of the Conceptual Model, there is an optimal configuration of the South-of-Delta Rule Curve. The optimum: (1) Maximizes capture of Delta surpluses; and (2) Minimizes south-of-Delta forecast delivery shortages. To accomplish these objectives (1) Stored water in upstream north-of-Delta storage facilities should not be moved to south-of-Delta storage facilities if it causes the projects to forego capture of Delta surpluses; and (2) Stored water in upstream north-of-Delta storage facilities should be moved to south-of-Delta storage facilities if it prevents the occurance of forecast delivery shortages.

Under the application of the maximum extent of operations flexibility (the point at which the ratio relaxation was analyzed), it was assumed that the most optimal South-of-Delta Rule Curve was also the most aggressive. In other words, the maximum extent operations flexibility simulations for each alternative were modified to always export as much as possible under each month's constraints. Upstream north-of-Delta stored water was exported very aggressively.

The following should be considered when using the most aggressive South-of-Delta rule curve possible for all simulations used in the evaluation: (1) Delta export benefits occur because of the relaxation of export restrictions; and (2) Delta export impacts occur because of aggressive, but sub-optimal operations rules. The benefits/impacts indicated by the results presented here are annual averages and should not be assumed to indicate that either any yearly benefit or any yearly impact is excluded in the simulations performed.

4.3 Evaluation of Maximum Export Operational Flexibility Schedule

As with any application of a planning model like DWRSIM, results should be relied on for their comparative differences between simulations, not for their absolute values. Figures 3 and 4 show the absolute results for the alternatives. In order to do a comparative assessment of the maximum operational flexibility, the No Action maximum export operations flexibility must also be determined.

In determining the maximum export operations flexibility of the No Action simulations, some shortages arise. For example, the assumptions of Delta export restrictions already in place do not match up with those that would be imposed on the simulation by use of a Delta export capacity reduction schedule as assumed for this analysis. In an ideal case, a simulation could be assessed for the Delta export restrictions already were in place and a suitable schedule of Delta export

capacity reduction could be imposed on the simulation, instead of the previously assumed Delta export restrictions. One difficulty is that the preexisting base would be redefined if a replacement Delta export capacity reduction schedule were assumed. A second difficulty is that a replacement schedule would replace Delta export restrictions that are widely modeled in a multitude of other models and simulations. Redefinition of the basic assumptions common to water management criteria A and B was not a consideration in this evaluation.

The No Action simulation under water management criteria B could not be redefined with a Delta export capacity reduction schedule because it can be assumed that a Schedule in the range of Schedule 11 or Schedule 12 would be reasonable for the No Action condition under water management criteria B. When interpreting Figure 4, Table 2 or other results, it is important to consider that approximately 48-56 days of export restriction already exist due to other assumptions common to water management criteria A and B.

In the case of the No Action simulation under water management criteria A, the option did exist to redefine the Delta export restrictions placed on the simulation by the assumption of water management criteria A. The procedure used is described in the following section. Figure 3 shows the results of this analysis, and in the case of water management criteria A, the No Action simulation does provide a complete basis of comparison for assess the operational flexibility gained under the alternatives.

Section 5 – Conclusions

The following conclusions can be drawn from the specific presentation of data in this analysis:

Delta Export Conveyance.
Increased Delta export conveyance capability provides increased operational flexibility in Above Normal and Wet years. Refer to Table 2, Table 3, Figures 3 and Figure 4. Under either water management criteria South Delta Improvements and Joint Point of Diversion lead to greater operational flexibility in wet years. Results are variable between the two water management alternatives, but indicate an operational flexibility gain of approximately 50 days.

Based upon the subsequent analysis of forecast delivery shortages and Delta export/inflow ratio relaxation schedules, this conclusion appears to remain valid assuming the application of Delta export/inflow ratio relaxation to 75% in August and September. However, this has not been sufficiently analyzed at this time.

North-of-Delta Storage.
Increased north-of-Delta storage facilities provides Critical through Below Normal year increased operational flexibility, depending on environmental restrictions. Refer to Table 2, Table 3, Figure 3, and Figure 4. Under either water management criteria, the addition of North-of Delta Surface Storage leads to greater operational flexibility in dryer years. Comparative results are variable, but indicate approximately 20 to 30 days of operational flexibility gained. The foregone Delta exports vary widely due to variations in assumptions between the two No Action conditions considered.

Increased north-of-Delta storage facilities provide Critical year operational flexibility if new prescriptive environmental restrictions are not imposed. The addition of North-of-Delta Surface Storage (NDSS) under water management criteria B, which does not restrict fill or release operations of the NDSS, indicate nearly 90 days of operational flexibility gained under Critical year conditions. Substantial Delta exports (> 500 TAF/YR) would be foregone in order to apply this level of operations flexibility.

Based upon the subsequent analysis of forecast delivery shortages and Delta export/inflow ratio relaxation schedules, this conclusion appears to remain valid assuming the application of Delta export/inflow ratio relaxation to 75% in August and September. However, this has not been sufficiently analyzed at this time.

South-of-Delta Operations.
As operational flexibility is utilized, south-of-Delta forecast delivery shortages arise. This conclusion is based upon the inspection of the DWRSIM model response to high level of application of operational flexibility under water management criteria B. It appears that new south-of-Delta storage facilities could be beneficial in overcoming forecast delivery shortages by providing a multi-seasonal south-of-Delta reserve storage space at the same time as maintaining existing within-season operational storage space. However, operations shortages appeared to be substantially reduced with relaxation of the Delta export/inflow ratio.

Delta Export/Inflow Ratio.
August and September Delta export/Delta inflow ratio relaxation to 75% provides for additional conveyance capability that assists in overcoming forecast delivery shortages. Referring to Table 4 and 5, the only Delta export/inflow ratio relaxation option that appears useful for enhancing and applying operations flexibility is relaxing the August and September ratio to 75%. This ratio relaxation option appears to have the greatest potential benefit under conditions in which forecast delivery shortages occurred. An increase in the operational flexibility of an alternative as assessed in Tables 2, Table 3, Figure 3, and Figure 4 appears to be minor. Use of the additional unrestricted export capacity under the ratio relaxation to move stored water from upstream north-of-Delta storage facilities, may preclude capture of Delta surplus water in the following Spring, resulting in the limitation of ratio relaxation benefits when forecast delivery shortages were not present.

APPENDIX

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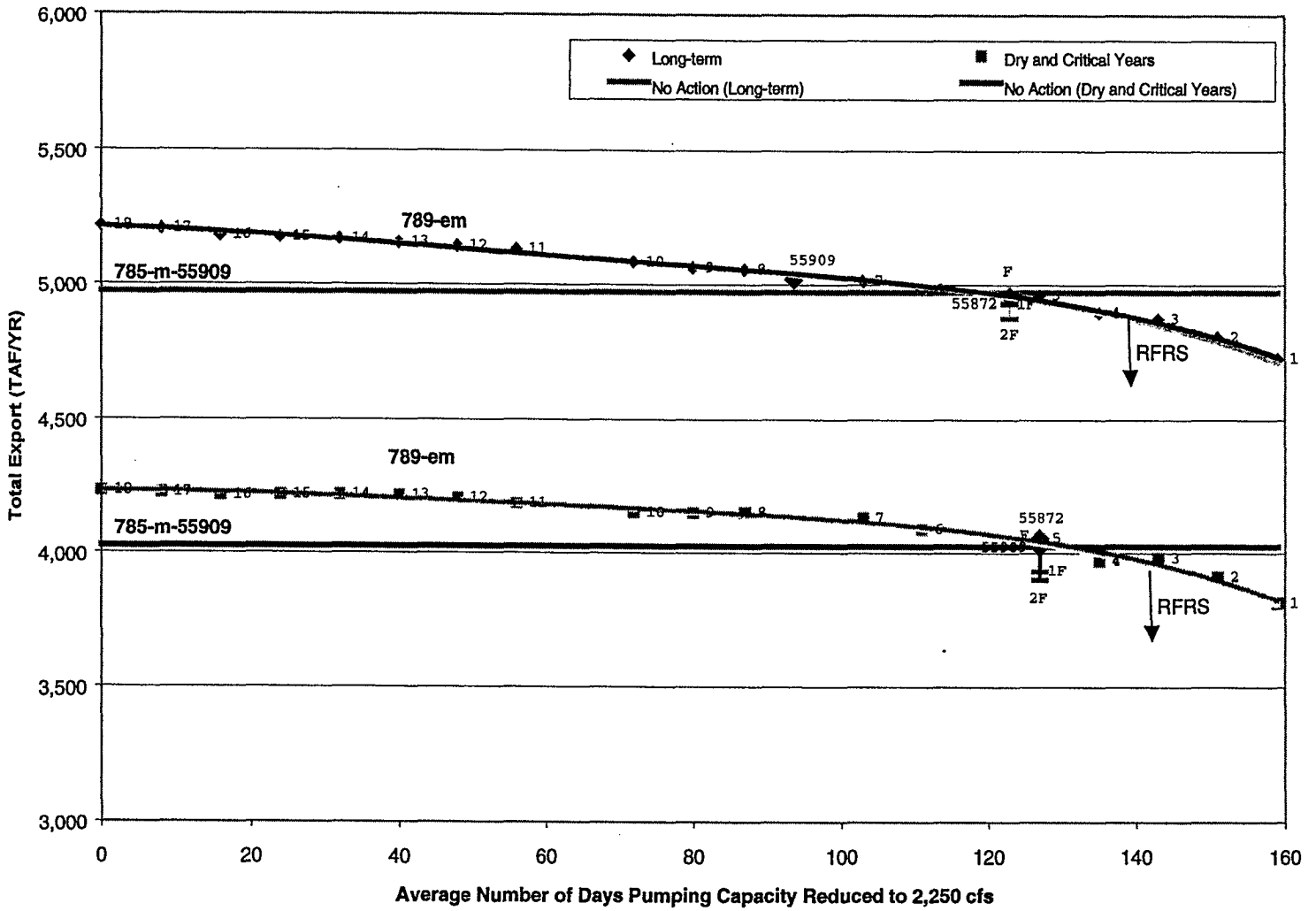

Figure A-1. Relationship between total Delta export and average number of days pumping capacity reduced to 2,250 cfs for Water Management Criteria A with South Delta Improvements and Joint Point of Diversion.

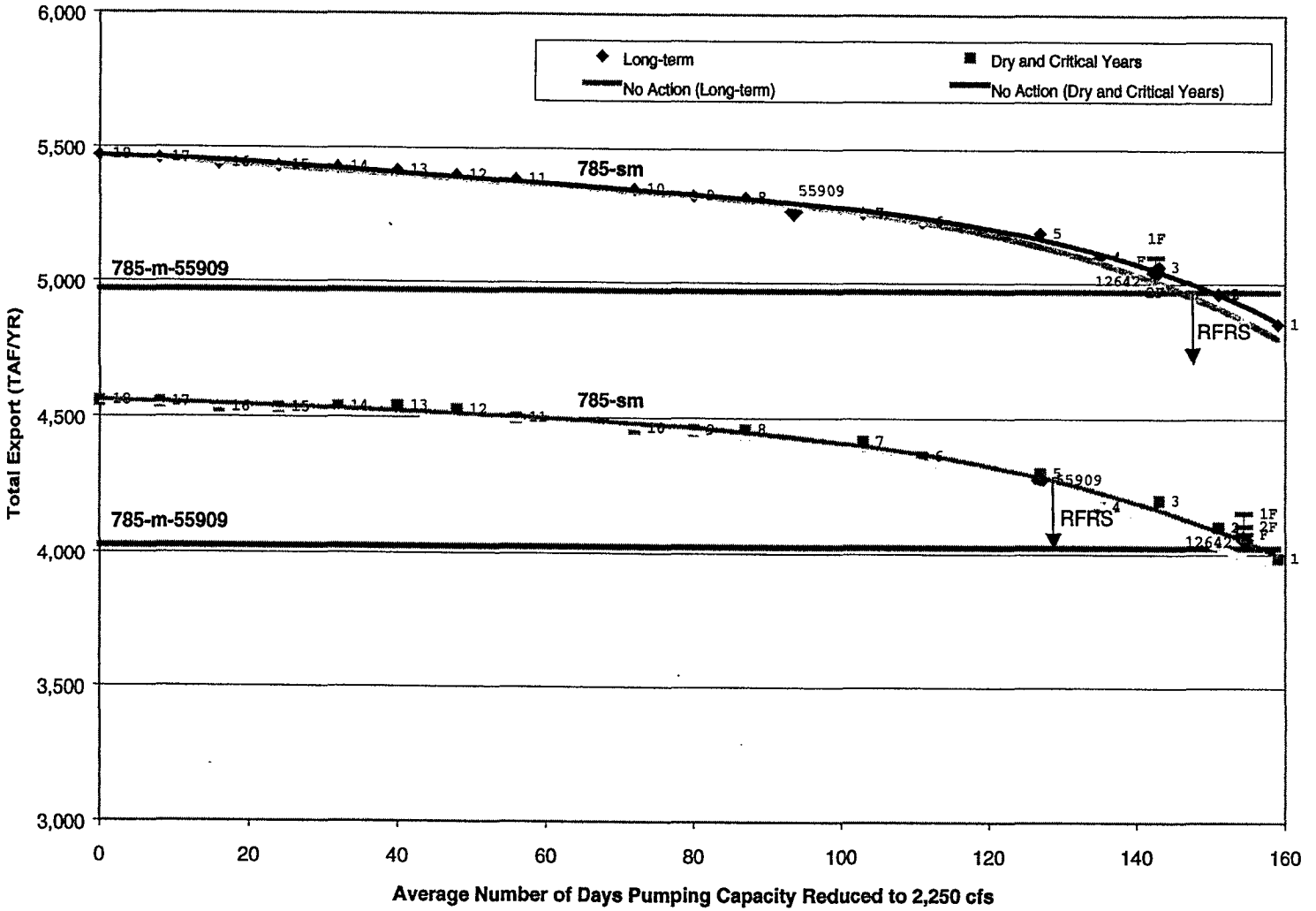

Figure A-2. Relationship between total Delta export and average number of days pumping capacity reduced to 2,250 cfs for Water Management Criteria A with South Delta Improvements, Joint Point of Diversion, and North Delta Surface Storage.

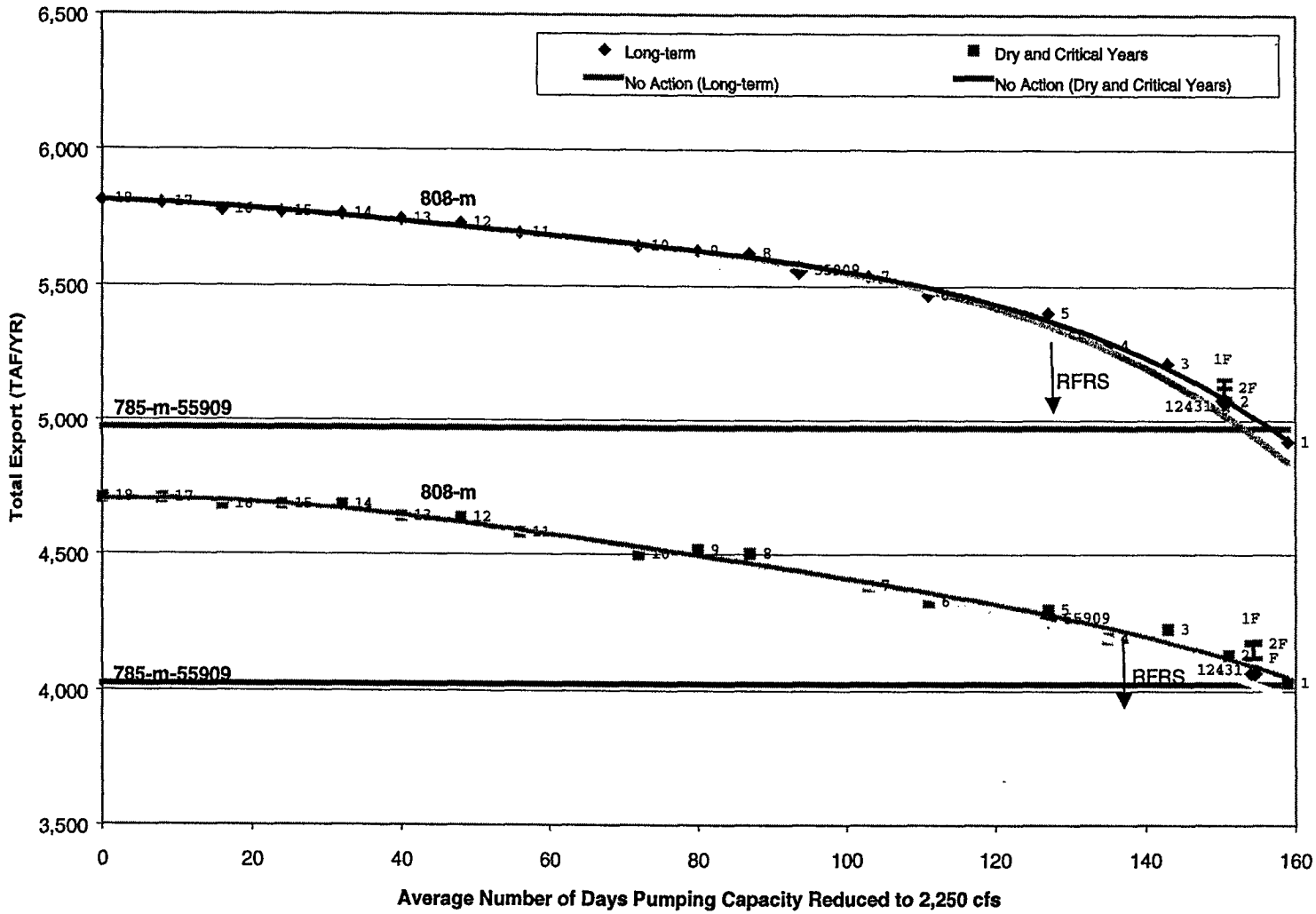

Figure A-3. Relationship between total Delta export and average number of days pumping capacity reduced to 2,250 cfs for Water Management Criteria A with South Delta Improvements, Joint Point of Diversion, and all storage options.

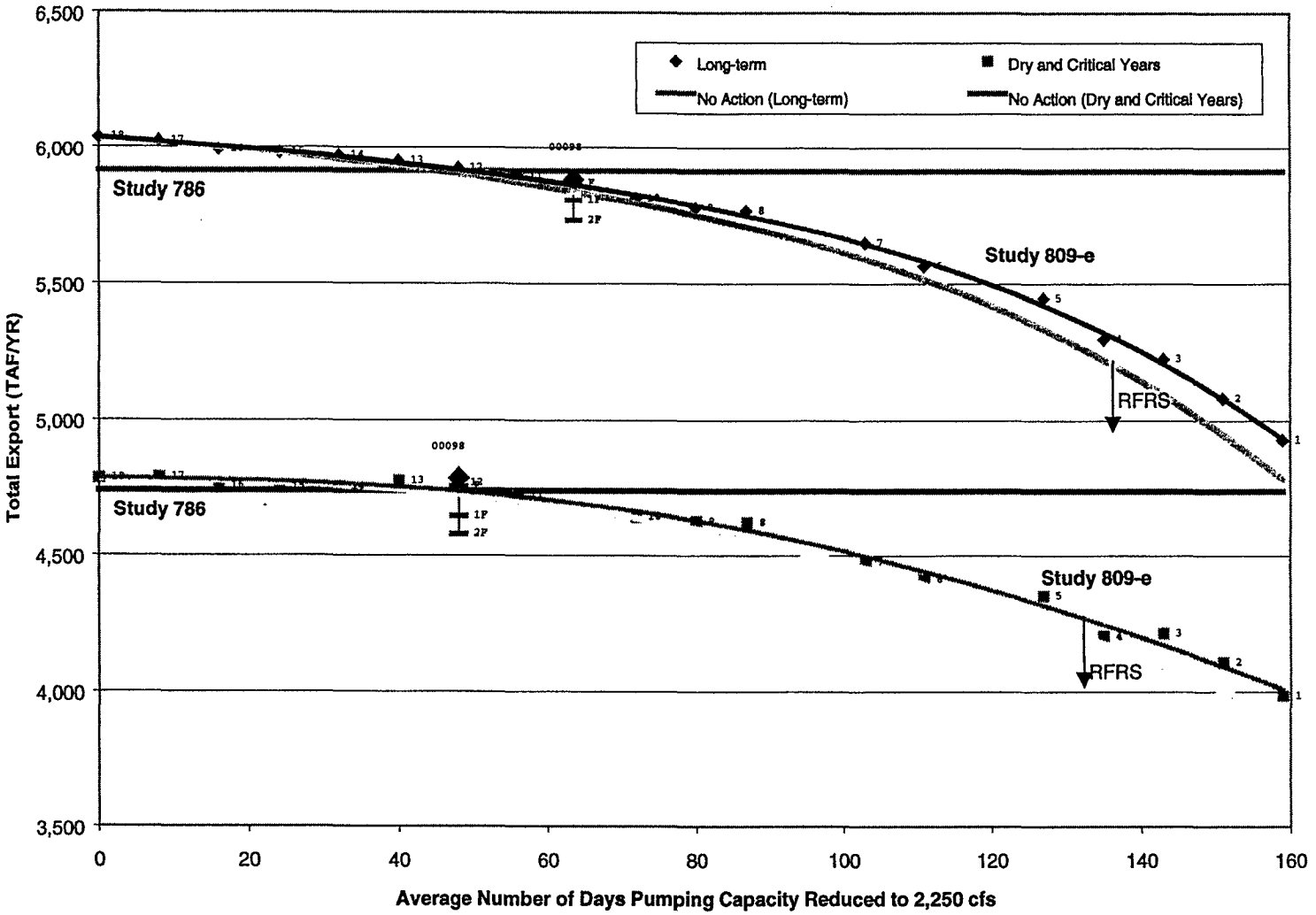

Figure A-4. Relationship between total Delta export and average number of days pumping capacity reduced to 2,250 cfs for Water Management Criteria B with South Delta Improvements and Joint Point of Diversion.

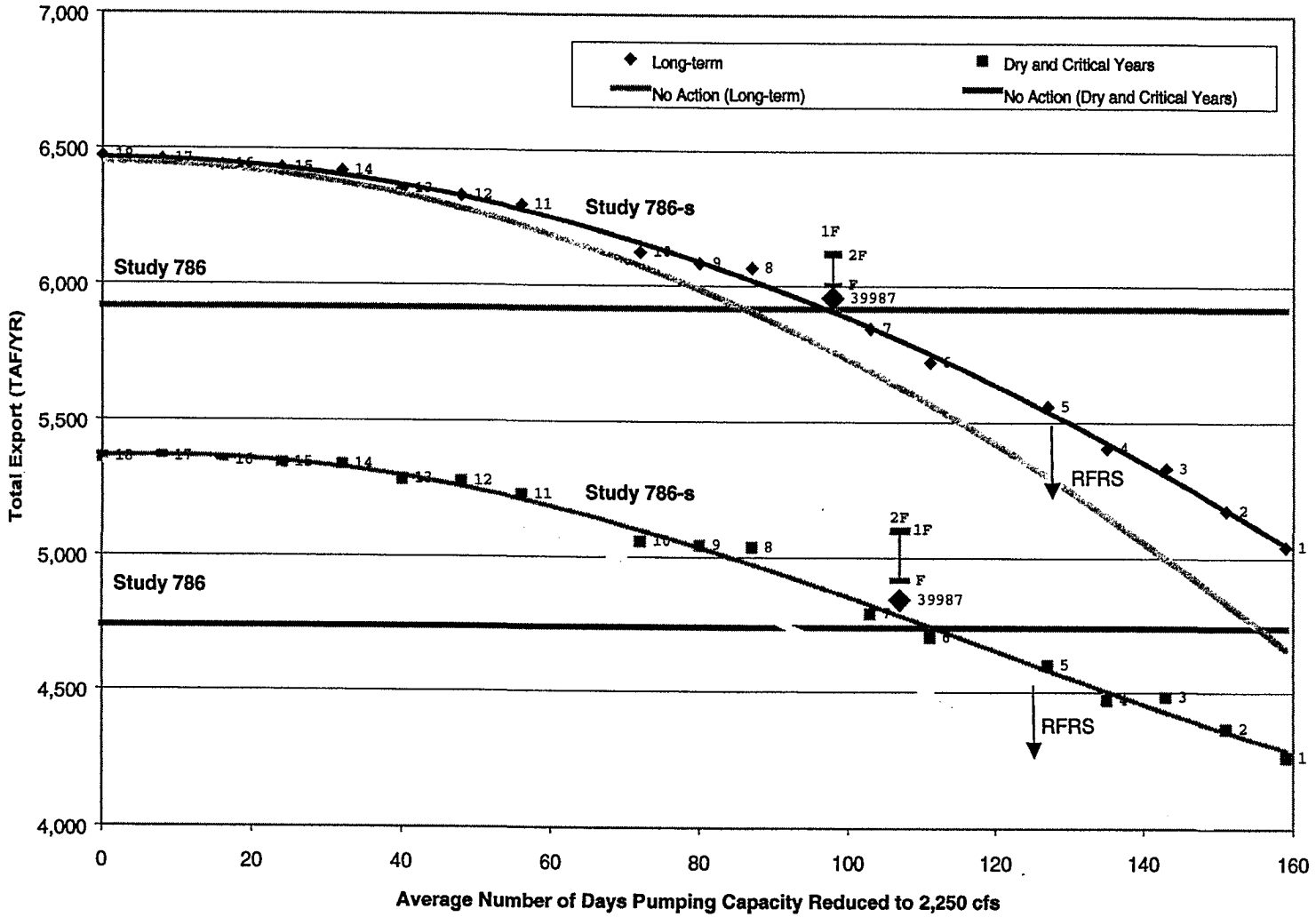

Figure A-5. Relationship between total Delta export and average number of days pumping capacity reduced to 2,250 cfs for Water Management Criteria B with South Delta Improvements, Joint Point of Diversion, and North Delta Surface Storage.

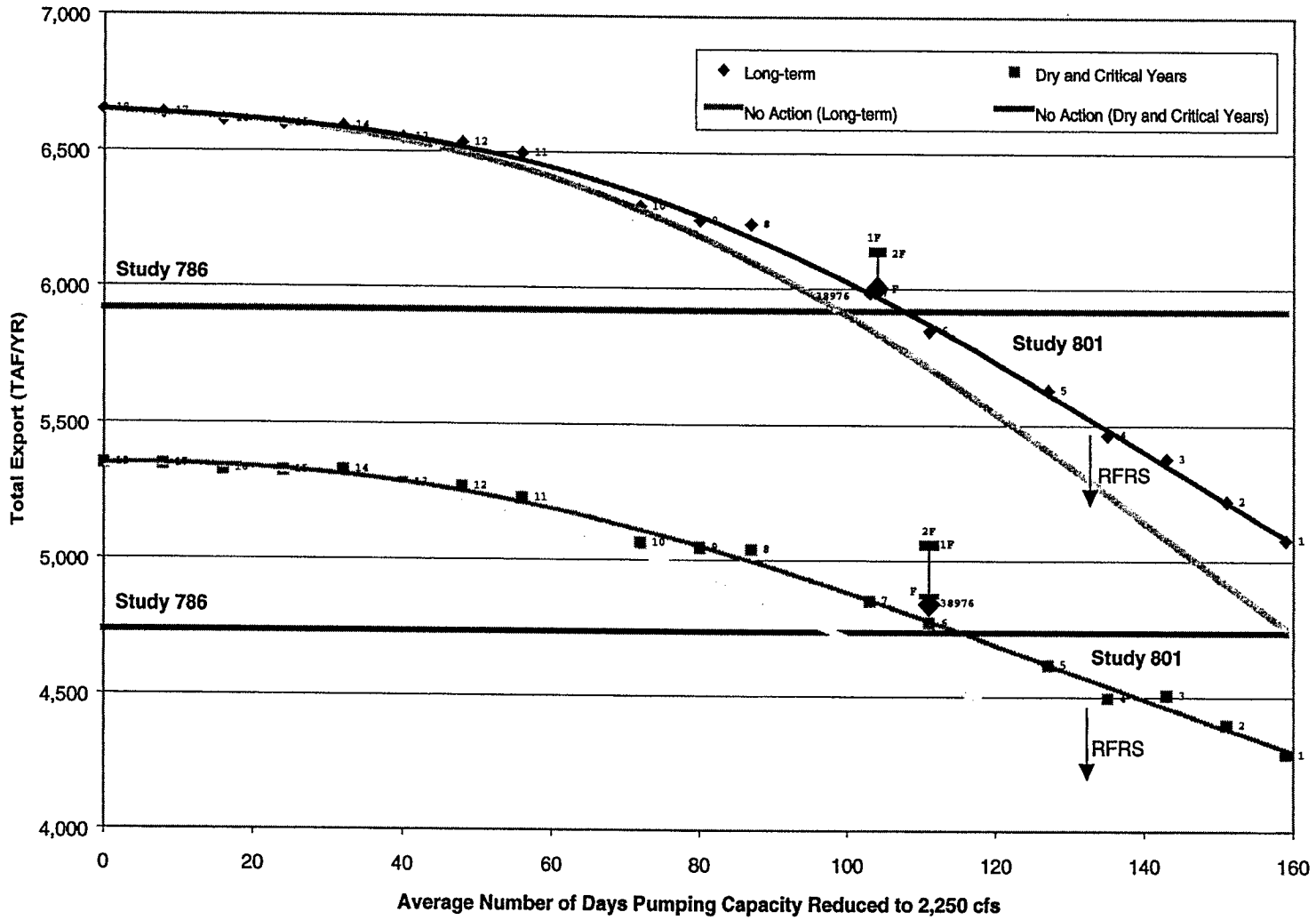

Figure A-6. Relationship between total Delta export and average number of days pumping capacity reduced to 2,250 cfs for Water Management Criteria B with South Delta Improvements, Joint Point of Diversion, and all storage options.

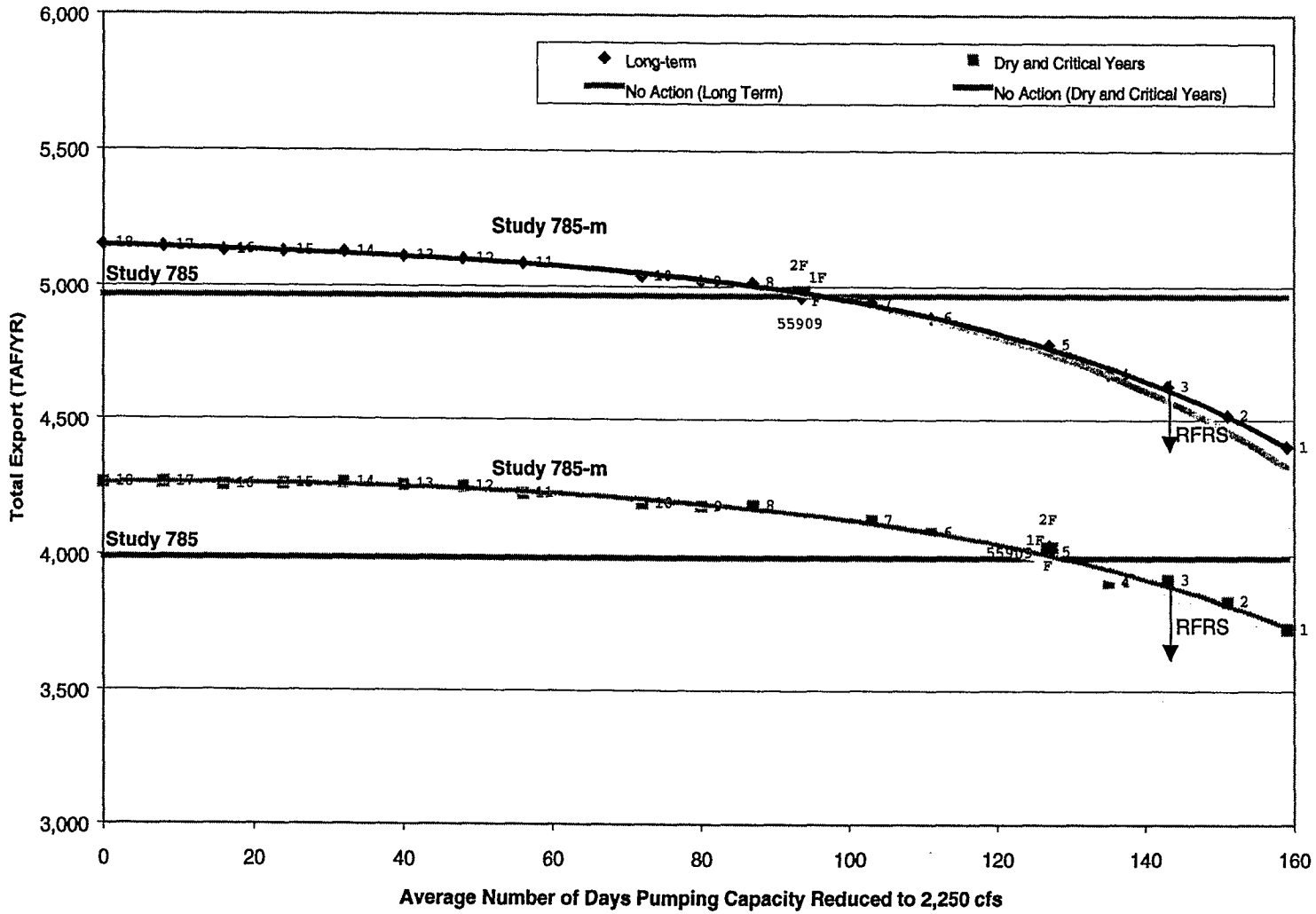

Figure A-7. Replacement of Water Management Criteria A Delta Restrictions

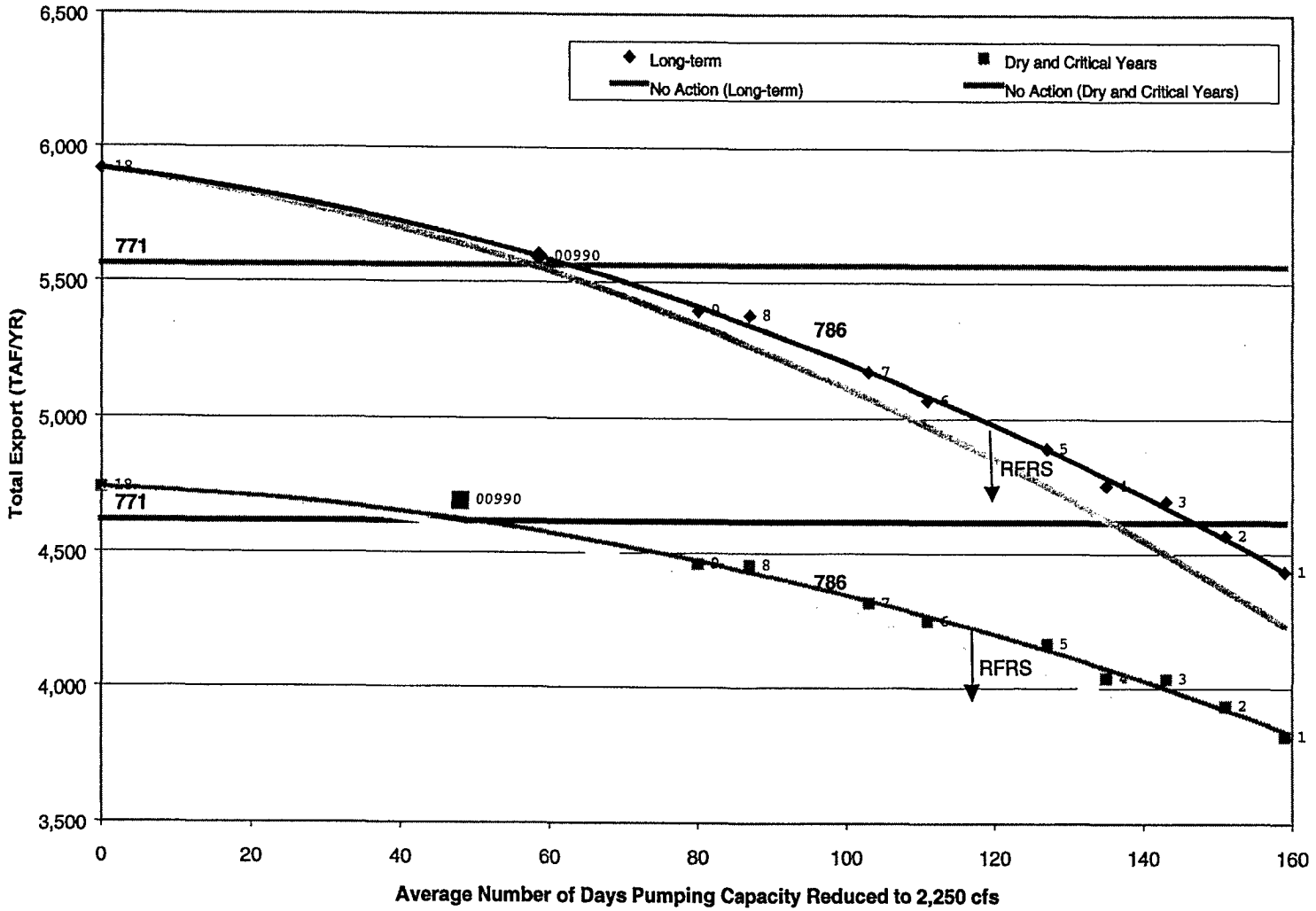

Figure A-8. Special Study: Environmental Flexibility Sensitivity to Demand Increase

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